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ABSTRACT

Results of preliminary tests made prior and subsequent to the installation of a two-way interactive communication system which involves a computer complex termed the Local Processing Center and subscriber terminals located in the home or business location are reported. This first phase of the overall test plan includes tests made at Theta-Com Corp. using actual two-way cable cascades, a two-way AML microwave link, and the prototype subscriber response system (SRS) terminals which are now in use in El Segundo, California. Data collected in the tests relating to the performance of the full SRS in operation with a 16-amplifier cascade are presented, and the factors which are important in the design of an interactive system, including the oft-neglected computer and its software component, are discussed. In addition, the El Segundo SRS installation is described and the services made operational are categorized and discussed. (Author/LB)

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THETA-COM
SRS

SUBSCRIBER RESPONSE SYSTEM
Progress Report

By Richard T. Callais
Manager, SRS Division

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SRS EL SEGUNDO INTERIM TEST REPORT

Richard T. Callais
Manager, SRS Division
Theta-Com of California
Los Angeles, California

INTRODUCTION AND SUMMARY

This paper is presented as a progress report covering tests made prior to and subsequent to the installation of the Subscriber Response system in El Segundo through May 1973.

This first phase of the overall test plan includes tests made at Theta-Com using actual two-way cable cascades, a two-way AML microwave link, and the prototype SRS terminals which are now in use at El Segundo.

Data taken in these tests indicate the performance of the full SRS system in operation with a 16-amplifier cascade are substantially error free in the presence of typical or even excessive thermal noise. Excellent performance was also obtained in the presence of simulated impulse noise and interfering CW carriers.

The factors which are important in the design of an interactive system including the oft-neglected computer and its software complement are discussed. The El Segundo SRS installation is described, and test results to-date are discussed.

Finally, the services which will be tested at El Segundo are categorized and discussed.

THE SRS SYSTEM

The SRS system is a two-way interactive system, the basic operation of which is illustrated in Figure 1.

The two-way interactive communication takes place between a computer complex termed the Local Processing Center (LPC), shown in Figure 2, and subscriber terminals located in the home or business location. The subscriber terminals consist of two basic units - a Modem, shown in Figure 3, and a Subscriber Console.

The Modem unit contains no operating controls and can be located behind the television set or in some other relatively nearby, unobtrusive location.

The Subscriber Console is connected to the Modem by a small diameter cable (nominally a maximum of 50 feet in length) and is intended to be located within view of the television set. Two models of the Subscriber Console are currently available. The SRS Model 101, shown in Figure 4, contains a simple 3-digit keyboard. The SRS Model 102, shown in Figure 5, has a full 0 to 9 numeric keyboard and a strip printer. A paper tape cartridge used in conjunction with the strip printer is shown in Figure 6.

The units shown are operating samples from the prototype production run of 30 terminals.

More detail describing the basic SRS system is available in Reference [1].

EL SEGUNDO TEST PLAN

Starting in September 1972, the Theta-Com SRS system has been under test on a Theta-Cable two-way CATV installation in the City of El Segundo, California.

Initial testing is being performed with 30 of the prototype SRS terminals and will be continued and extended with the production and installation of 1,000 pre-production terminals starting at the end of 1973.

The initital tests using 30 terminals will combine technical testing and demonstrations and development of the services offered. These studies will continue as the 1,000 units are installed and will phase into the delivery of actual services.

EL SEGUNDO CABLE SYSTEM

The CATV system installed in El Segundo by Theta-Cable is a two-cable system, shown in Figure 7[1]. The system consists of an "A" cable system and a "B" cable system. The "A" cable trunk line is intended for downstream transmission only in the band from 54 to 260 MHz. The "B" trunk line operates bi-directionally: downstream from 174 to 260 MHz, and upstream from 5 to 108 MHz. The "A" cable distribution system, however, operates bi-directionally with the upstream bandwidth between 5 and 30 MHz. Upstream signals from "A" distribution line are routed through appropriate low pass filters to the "B" trunk where they travel

[1]Diagram furnished by Mr. Thomas H. Ritter, TelePrompTer Corporation.

upstream to the head end and are routed to the SRS Local Processing Center. The "A" trunk, and distribution system, is intended primarily for home subscribers while the "B" trunk is intended for municipal, business, and industrial usage, where the greater upstream bandwidth (5-108 MHz) can be utilized for additional data communication and/or upstream video channels.

The "A" cable system will contain 32 trunk amplifiers and 124 line extenders. The "B" cable system will contain 32 trunk amplifiers and only 4 line extenders, in view of the smaller distribution demand anticipated from the specialized users.

The longest cascade in the system consists of 7 trunk amplifiers and 2 line extenders. Total plant mileage is approximately 30 miles. For the trunk, 3/4" foam dielectric cable will be used and 1/2" cable for the distribution system.

PRELIMINARY TESTS

While the El Segundo cable system was under construction, extensive testing of the SRS system using actual cable cascades was performed at the Theta-Com plant. This testing and other developmental efforts are continuing at Theta-Com using a second LPC following installation of the first LPC in El Segundo.

DUAL CABLE TESTS

A two-way two-cable system, representative of the El Segundo installation was assembled at the Theta-Com facility in Los Angeles. The cable cascade is shown in Figure 8 installed in a large temperature chamber where it has been extensively tested. Reels of aluminum sheath cable similar (except for smaller diameter) to the actual trunk cable are used to provide a 20 dB spacing measured at 260 MHz between amplifiers. Sixteen downstream amplifiers are used in the "A" trunk system and sixteen two-way amplifiers are employed in the "B" cable trunk.

For the El Segundo system, Jerrold SP-1/2/5-2W trunk amplifiers and SLE-300-2W line extenders are used.

Tests were made using an SRS 101 terminal and the full LPC computer complex feeding the aforementioned cascaded cable system. During the tests, 12 channels of video were being carried over the cable, plus the FM band. Computer controlled operation of all of the basic services, including channel selection, channel polling, meter reading, opinion polling, premium and restricted TV control, accessory power control and emergency alarms were repeatedly demonstrated satisfactorily.

Tests were also conducted to determine two-way system error performance. For these tests, a special LPC computer program was written to control the transmission of downstream commands such that four different commands were sent to an SRS terminal in sequence and the cycle was repeated indefinitely. In response to each of these commands, the terminal transmitted upstream different responses in accordance with the downstream command. These tests were performed using the 16-amplifier dual cable cascade.

The computer compared the responses to each command with the normal response expected and periodically read out to a teletype the total number of errors and the type of error. Over a period of 11 hours during which approximately 40 million complete two-way transmissions, comprising a total of 2.5 billion bits, were made with no errors. This error value corresponds to a bit error rate of 4×10^{-10} if we assume the next transmission (after the end of the actual test) were to contain an error. This would correspond to a signal to noise ratio of roughly 17 dB [2]. Actually, the S/N ratio was in excess of 40 dB, and the corresponding error rate due to thermal noise in the test cascade with this S/N would be vanishingly small.

For actual field installations, the excess thermal noise from each upstream amplifier will add since the signal paths all converge to the trunk and eventually the Head End and LPC. For an extremely large CATV system, perhaps close to a worse case, let us assume we have approximately 300 miles of strand, and 1,000 reverse amplifiers. The resulting S/N calculated for reverse amplifiers with a noise figure of 10 dB, 23 dB of gain, operating at a +32 dBmV output level is 28 dB for a 4-MHz bandwidth [3]. This will again result in a vanishingly small error rate for data signals but a very poor upstream video signal.

In El Segundo, there will be approximately 160 reverse amplifiers which will cause no thermal noise problems for the SRS but may degrade video picture quality. In this event, provision has been made to operate in a type of hub fashion with two trunk lines in place of one, or to use the B cable distribution lines for video.

Some attempt was made to determine the performance of the system with simulated impulse noise and with interfering carrier signals.

Impulse noise such as might be produced by ignition noise or corona from a high voltage power line was simulated by using 50 nanosecond pulses at repetition rates which were varied from 100 Hz to above 100 KHz. The exact pulse width was varied to place

the peak of the resulting noise spectral distribution at the center frequencies of the downstream and upstream SRS carriers, i.e., 110 MHz and 23 MHz, respectively. The levels of the impulses were adjusted for the highest value which did not produce errors. No errors were observed in either downstream or upstream transmissions for a peak SRS carrier level to equivalent 4 MHz bandwidth RMS noise ratio of 14 dB. During the downstream measurements, the noise signals on TV Channels 2 thru 6 were such that the video picture was badly disturbed, while Channels 7 thru 13 were also seriously degraded.

In the case of CW interference such as might be produced by radiation from a broadcast station, the interfering carrier was swept across the SRS downstream and upstream bands and the amplitude varied until errors were detected. The peak SRS signal carrier to CW carrier beyond which errors would occur was measured at 20 dB for downstream reception, while the upstream value was 6 dB. The excellent behavior in the upstream direction is attributed to the hard limiting employed in the upstream PSK receiver, which produces a "capture" effect.

In the above tests, the SRS downstream and upstream carrier levels were approximately the same as the respective TV video carrier levels.

With regard to CW interference and impulse noise, SRS utilizes a high pass filter and a frequency converter between the drop line and the TV set which will effectively block spurious signals picked up at the subscriber's TV set from entering the cable in the upstream direction. Entry of these interfering signals outside the home can be prevented where they occur by effectively shielded drop lines and good workmanship in the installation of the entire cable system.

SINGLE CABLE TESTS

While the El Segundo installation is a two-cable system, it is believed that there also will be many applications where single cable systems will be used for two-way communication. For this reason, SRS is also currently undergoing operational tests using the single cable cascade shown in Figure 9.

This system utilizes a cascade of 16 Theta Com XR2 two amplifiers and a line extender, with 22 dB spacing measured at 270 MHz between trunk amplifiers.

In addition, to demonstrate the practicability of complete two-way CATV system operations including Local Distribution Service, a Theta-Com two-way AML multichannel microwave link was added to the system. The AML system relays the Head End VHF and LPC SRS downstream signals to the cascade which, in turn, drives the SRS terminal and TV receivers. Return signals from the SRS terminal and a TV camera are fed back upstream thru the cascade to a second AML transmitter. A second AML receiver feeds the upstream SRS and video signals to the Head End and Local Processing Center to complete the two-way loop.

The overall system is shown in the functional block diagram of Figure 10. The entire system performed successfully, and was demonstrated live at the 1972 NCTA Convention using the actual hardware. It was inconvenient to transport the Local Processing Center for display at the NCTA Convention, and in its place a small fixed program computer was constructed to demonstrate some of the basic services. A computer display panel, shown in Figure 12, was also designed to clearly display the performance of various services.

An interesting and potentially popular and useful service is demonstrated in this equipment. A TV camera at the subscriber terminal relays TV pictures upstream of the home or business location. The camera is actuated by an accessory control command signal which can be furnished by the LPC at any desired time. The upstream video information is converted in frequency at the Head End to a restricted channel (Channel F) and is redirected downstream to an eligible subscriber or subscribers, whose individual eligibility to view the channel is controlled by the LPC. Thus, a video program initiated anywhere in the cable system can be routed to any particular subscriber, group of subscribers, or all subscribers in the CATV system.

Important applications of this service include the following:

a) Home or business protective surveillance and relay of both video and digital alarm signals to the appropriate protective agency or municipal arm.

b) Educational instruction in the home or local schoolroom with relay to the educational center and/or other students.

c) The relay of civic, sporting or news events from any place within the cable system to the home on a fee or free basis.

In addition to single cable two-way systems which can be installed with integral two-way distribution equipment in new construction, there is also the need to retrofit existing one-way systems with two-way capability at minimal cost.

In these cases, the existing downstream amplifiers will be retained and new upstream amplifiers and filters will be retrofitted into the system. The cascade shown in Figure 11 is applicable to the situation. It consists of 32 existing Theta-Com XR downstream amplifiers, retrofitted with 16 Theta-Com XR2SL amplifiers and 32 XR2CF series filters for upstream transmission. The downstream amplifiers are mounted on the front of the racks while the upstream retrofitted components are mounted on the top.

COMPUTER SOFTWARE CONSIDERATIONS AND TESTS

It needs to be emphasized that a successful two-way interactive communication involves not only subscriber terminals, a two-way cable system, and equipment to modulate and demodulate data signals on r.f. carriers - but also a reliable and efficient computer system which is generally associated with the head end. The computer, in turn, requires software control to perform its function of interrogation of the subscribers and more important, servicing the subscriber's needs.

It would be misleading to consider only the time required to interrogate subscribers if we wish to determine the actual time a given two-way system requires to handle the subscriber's requests. The degree of traffic volume and diversity of services which can be accommodated by a given computer software system are also significant factors in evaluating the overall capability of a two-way system.

In these early days of two-way CATV systems, these considerations may be overlooked, or de-emphasized as less important than introducing some form of hardware into public test and use as soon as possible. While the view is to some extent understandable, it may be shortsighted from the cable system operator's vantage in that it may lead to early obsolescence of systems which are limited in the ability to handle large numbers of subscribers and many services or which cannot service heavy traffic demand economically, efficiently, or at all.

Viewed in proper perspective, rapid interrogate and response times, however, are certainly important qualities for any effective system. Two factors determine this portion of the total servicing time required: first, the speed of data transmission

and second the effect of propagation delay of the cable system.

The SRS system transmits digital data downstream and upstream at a rate of 1 megabit per second. The effects of propagation delay are effectively reduced to a negligible amount in the SRS system by the use of proprietary system design features. The combination of the relatively high bit rate and the reduction in the effects of propagation delay permit a total basic interrogation and response time less than approximately 2.4 seconds for 50,000 subscribers.

In systems which do not effectively eliminate the effect of propagation delay, interrogation-response sequences must allow a time delay equal to twice the propagation time between the computer and the farthest subscriber in order to avoid the possibility of interfering responses from 2 subscribers. For a maximum cable distance of 10 miles, the comparable time required to poll 50,000 subscribers would increase to approximately 7.9 seconds, an increase of approximately 325% in elapsed time. Depending on the service being provided, there may be several interactive contacts required between computer and subscriber to complete the required sequence of events which will increase the service time proportionately.

The use of two-way microwave relays between the head end and the cable system will also directly add further propagation delay depending on the length of the microwave path. For an additional 10 miles due to microwave link path length, the time to service 50,000 subscribers would increase from 7.9 seconds to approximately 13.3 seconds, while the SRS service time would remain substantially constant at 2.4 seconds.

Other significant factors in determining actual service time are the speed of the operation of the computer in performing instructions, the core memory cycle time, the access times to disk memory and magnetic tape recorder, when required, and the overall efficiency of the software program controlling the data processing task. The time required for the performance of these operations is generally additive to the basic interrogate-response times discussed previously, since the subscriber responses must be received by the computer before the processing of the responses and service requests can occur. Related to these factors are the economic factors involving tradeoff considerations with respect to the cost of the computer and its peripherals. Increasing the amount of core or semiconductor memory used, for example, may speed up service time but the cost may increase prohibitively.

Depending on the selection of the computer, its peripherals, and the programming efficiency, the actual time to service 10,000 subscribers with a variety of services and heavy traffic volume may increase prohibitively for services in which the interaction time should be short (say, 10 seconds or less) to be attractive to the subscriber.

The SRS computer hardware and software have been selected and designed to permit the economical delivery of services to subscribers under heavy traffic conditions generally within a few seconds. In the Theta-Com laboratories, a computer program was prepared to simulate the simultaneous purchase of any Premium TV channel by 1,000 subscribers. The average time required to provide this service to the 1,000 subscribers was measured at 1.7 seconds. This time included preparing a billing record of each purchase on magnetic tape.

These simulation tests will be continued and extended to include different "mixes" of the various services and variable traffic volumes.

In the field at El Segundo, various tests are being conducted which are intended to proof test the software design and overall system performance under dynamic conditions. When 1,000 terminals have been installed, traffic handling performance can be demonstrated based on real-life requirements. Other tests planned include intercommunication between the SRS Local Processing Center and other data processing and computer systems such as time shared large scale computers, reservation systems, message switching and merchandising systems.

EL SEGUNDO SRS INSTALLATION AND TESTING

Upon completion of the head end building in August 1972, the SRS Local Processing Center was installed and operative by September 1, 1972.

The head end building is shown in Figure 13, and the LPC installation therein, in Figure 14.

An apartment was obtained in El Segundo to use as a test site and to permit demonstrations to interested parties. The apartment location is designated as "Test Site" in the El Segundo CATV system diagram shown in Figure 15. The encircled numbers in Figure 15 refer to the number of the trunk amplifier in terms of total number of series trunk or sub-trunk amplifiers from the head end.

The apartment is located at the most distant point in the El Segundo system-i.e., a route including 7 trunk amplifiers and 1 line extender amplifier.

An SRS terminal in use at the apartment test site is shown in Figure 16.

Three SRS terminals have been installed at the El Segundo apartment, together with an operative security alarm system.

Numerous successful demonstrations of two-way message capability, emergency alarms, accessory power control, premium television, restricted channel control and other services have been performed since September 1972. Some 14 SRS terminals have been under test on the El Segundo cable system - distributed among the apartment, private homes and the head end. This will be extended to approximately 25 terminals located in various private dwellings in the city.

In conjunction with the 1973 NCTA Convention and Exhibition at Anaheim, California starting on June 17, 1973, SRS terminals will be demonstrated in operation on the cable system at the Hacienda Motel in El Segundo.

The test results to-date indicate SRS is capable of excellent performance when the cable distribution system is properly installed and functioning. In a recent test, for example, the SRS system was operated for a total of 60 hours continuously. During this time the LPC computer transmitted a total of 1.44 billion 22 bit words downstream addressed to a total of 10,000 individual terminals. Actually only 14 terminals were on the cable system during the test. These 14 terminals returned a total of 2.02 million 17 bit words in reply to the downstream transmissions. A total of 15 errors were detected by the LPC computer during the entire test. Of these errors none were correlated with responses from the 14 terminals installed on the cable system; the total of 15 errors were attributed to spurious noise generated during periods when the 14 terminals were not in the process of transmitting replies.

These tests will be continued and refined as the overall test progresses; it is planned for example to include a "universal" terminal on the line which will respond to 10,000 different addresses with predetermined replies. This will enable closer correlation of errors with transmissions and will further serve to exercise the software and data processing system

The problems encountered to-date have been largely related to cable distribution system components and installation practices. Included in this category are loose, intermittent or faulty connectors and inadequate grounding, particulary at house drops.

The addition of an upstream path to the normal downstream-only CATV distribution system requires a different focus of attention and concern for installation details and procedures than is generally required for one-way television service.

The results to-date indicate, however, that no problems have occurred which have not yielded to patient application of trouble shooting techniques.

A major technical objective of the El Segundo tests will consist in the definitization of distribution system component performance standards and installation procedures which are required for efficient two-way communication.

The initial SRS system design has anticipated the potential impact of noise by incorporating noise resistant terminal and computer system techniques and the experience gained thus far in the testing has led to further improvements in these areas.

TESTS OF SERVICES

The various services which will be tested by the SRS system can be categorized broadly as follows:

a) New Services: Services which are not widely available to the public at present.

b) Existing Services: Services which are presently available at the home using other means, but which would provide some improvement to the public or other user such as personal convenience, cost savings, greater flexibility, time savings, etc.

Under "New Services", we may list Premium Television, Restricted Channels, Frame Grabbing, Channel Polling, Opinion Polling, Interactive Education in the Home, Audience Participation, Off-track Betting (where legalized).

Under "Existing Services", we may list Meter Reading, Shop-at-Home, Reservation Services, Emergency Services, and various derivatives of these services.

The "New Services", by definition, will provide new experiences for the public which may well be attractive enough by themselves to gain widespread acceptance of interactive CATV.

Conversely, the improvements which may be offered by some of the "Existing Services", such as Shop-at-Home may furnish the initial trigger for widespread utilization of interactive services.

Once significant acceptance is obtained for some of the services, the cost of home terminals can be substantially justified on the basis of the additional revenues provided. At this point, some of the services listed as "Existing Services" may well be diverted from their present media to CATV. This could occur on the basis of the added improvements referred to above, the formation of new public habit patterns, and increasing availability of CATV and interactive systems in competition with other established media.

In El Segundo, it is planned to test the aforementioned services and others, where practical. The initial tests utilizing some 30 Subscriber Terminals will be developmental tests to demonstrate and develop the services for cable system operators and other enterpreneurs in a realistic environment, i.e., on an operating two-way cable system in subscribers' homes. The tests will take place over, perhaps, six months and phase into testing 1,000 terminals as they are installed in subscribers' homes.

The tests utilizing 1,000 terminals will deliver actual services to the subscribers on a fee basis, where applicable. The reaction of the subscribers to these services, the profitability of the services, and the need for change or modification in the implementation of the services will be studied in this phase.

CONCLUSION

The El Segundo tests are planned to comprehensively demonstrate the technical feasibility of two-way interactive CATV communications, and to attempt to determine public acceptance of the services offered.

With regard to technical feasibility, the results to date have corroborated and considerably extended previous test evidence obtained in the field at Los Gatos, California in 1971, indicating basic soundness of the SRS system design.

With regard to public acceptance, the El Segundo tests will constitute a serious and significant attempt to interact with the life style of the public to determine the roles best suited to this new technological medium and to demonstrate and measure its public value and marketability.

REFERENCES

[1] R. T. Callais and E. W. Durfee, "The Subscriber Response System," paper presented at the 1971 NCTA Convention.

[2] E. D. Sunde, "Ideal Binary Pulse Transmission by AM and FM," The Bell System Technical Journal, November, 1959, pg. 1408.

[3] System Applications brochure for XR2 Equipment, published by Kaiser CATV Division (now Theta-Com CATV Division), Phoenix, Arizona, pg. 43.

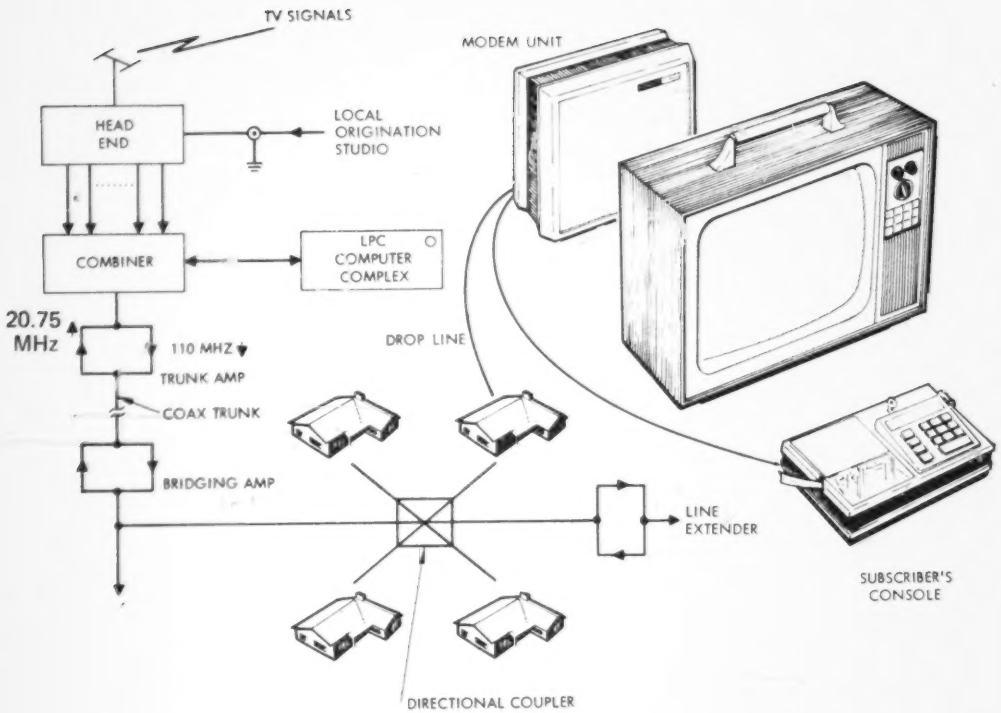

Figure 1 - Overall CATV Two-Way System

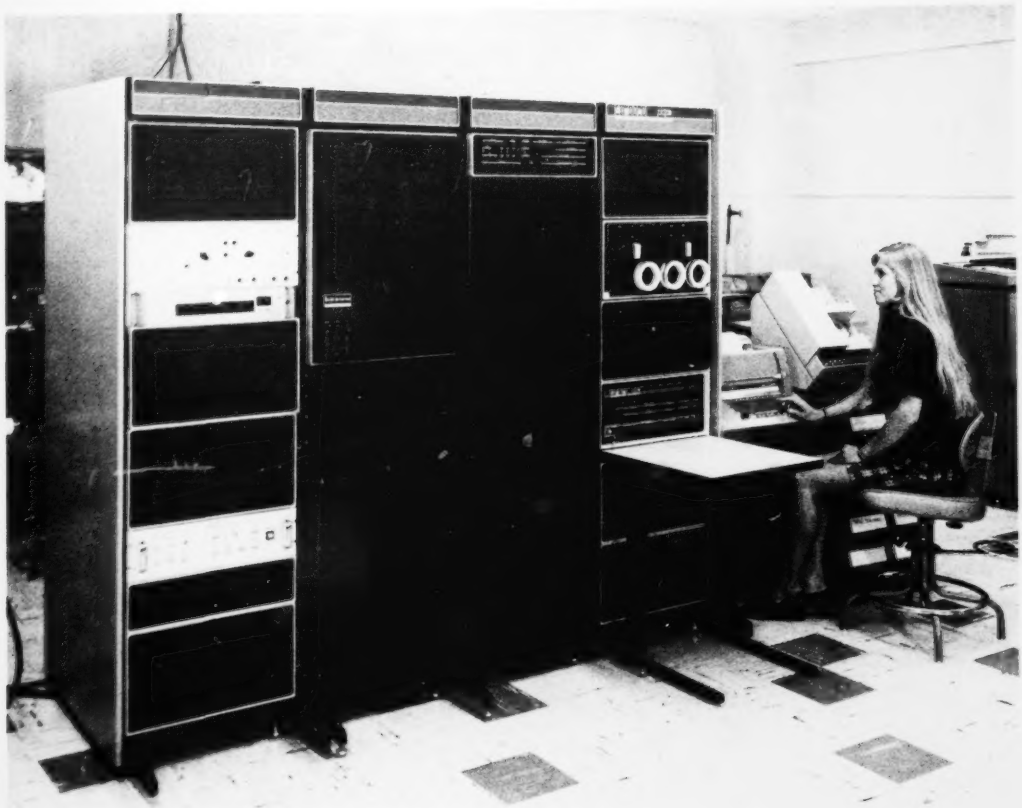

Figure 2 - SRS Local Processing Center

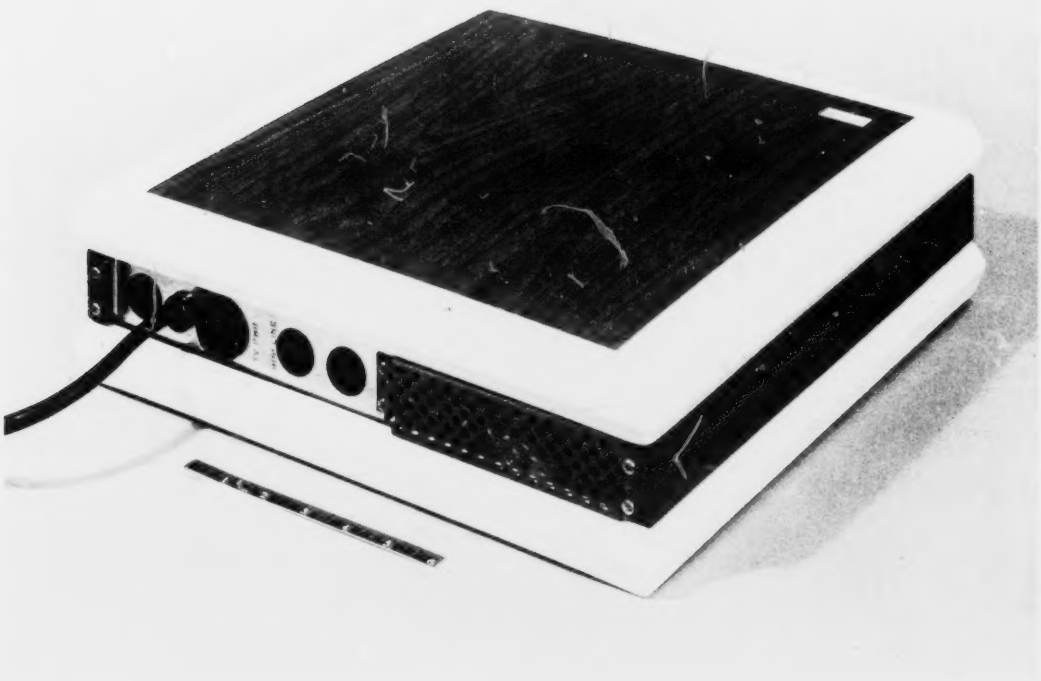

Figure 3 - SRS Modem Unit

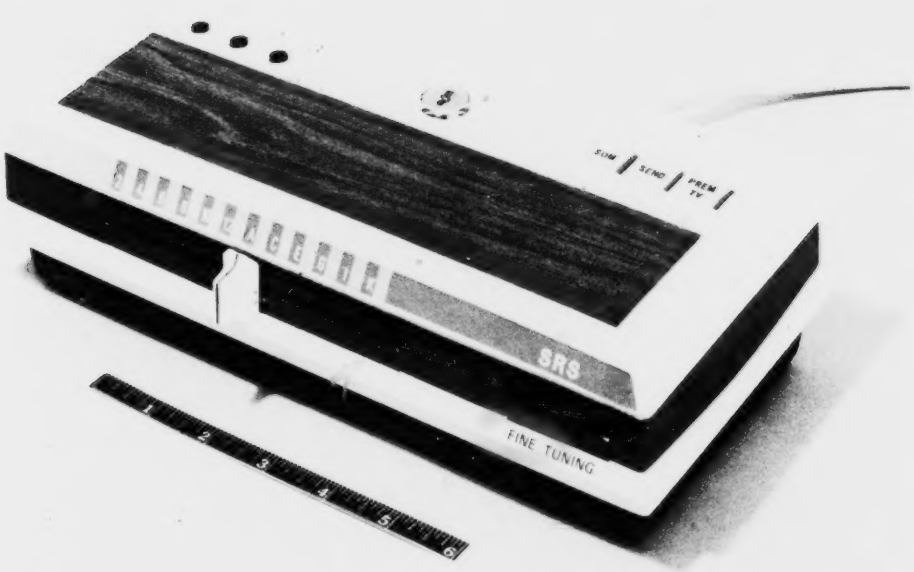

Figure 4 - SRS Model 101 Console

Figure 5 - SRS Model 102 Console

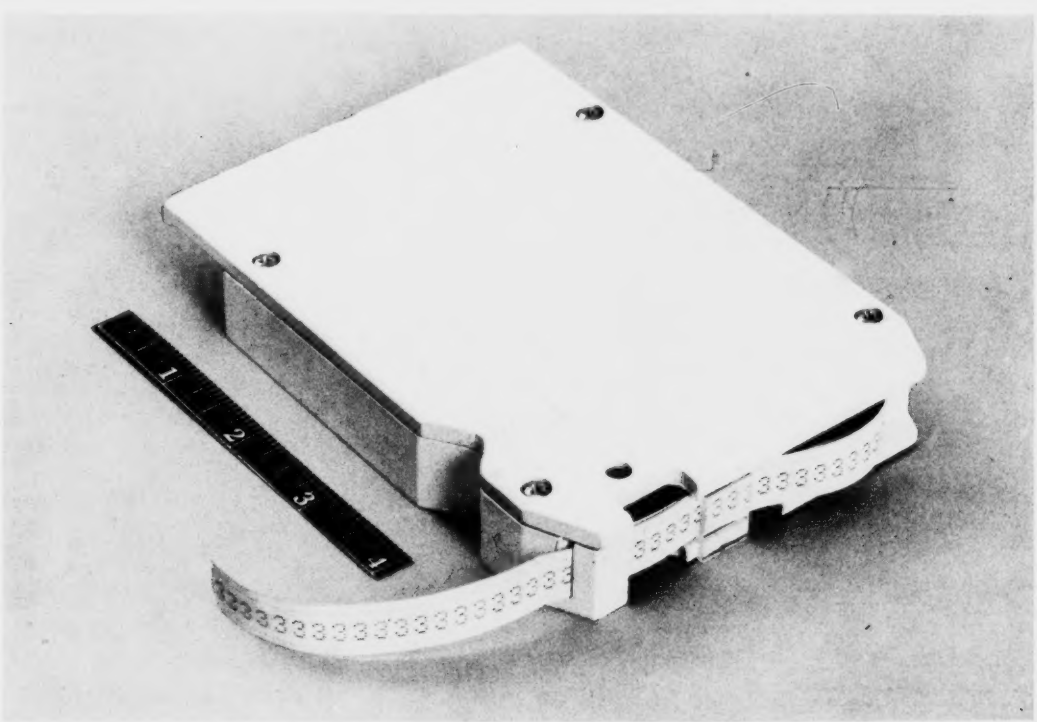

Figure 6 - SRS Paper Tape Cartridge

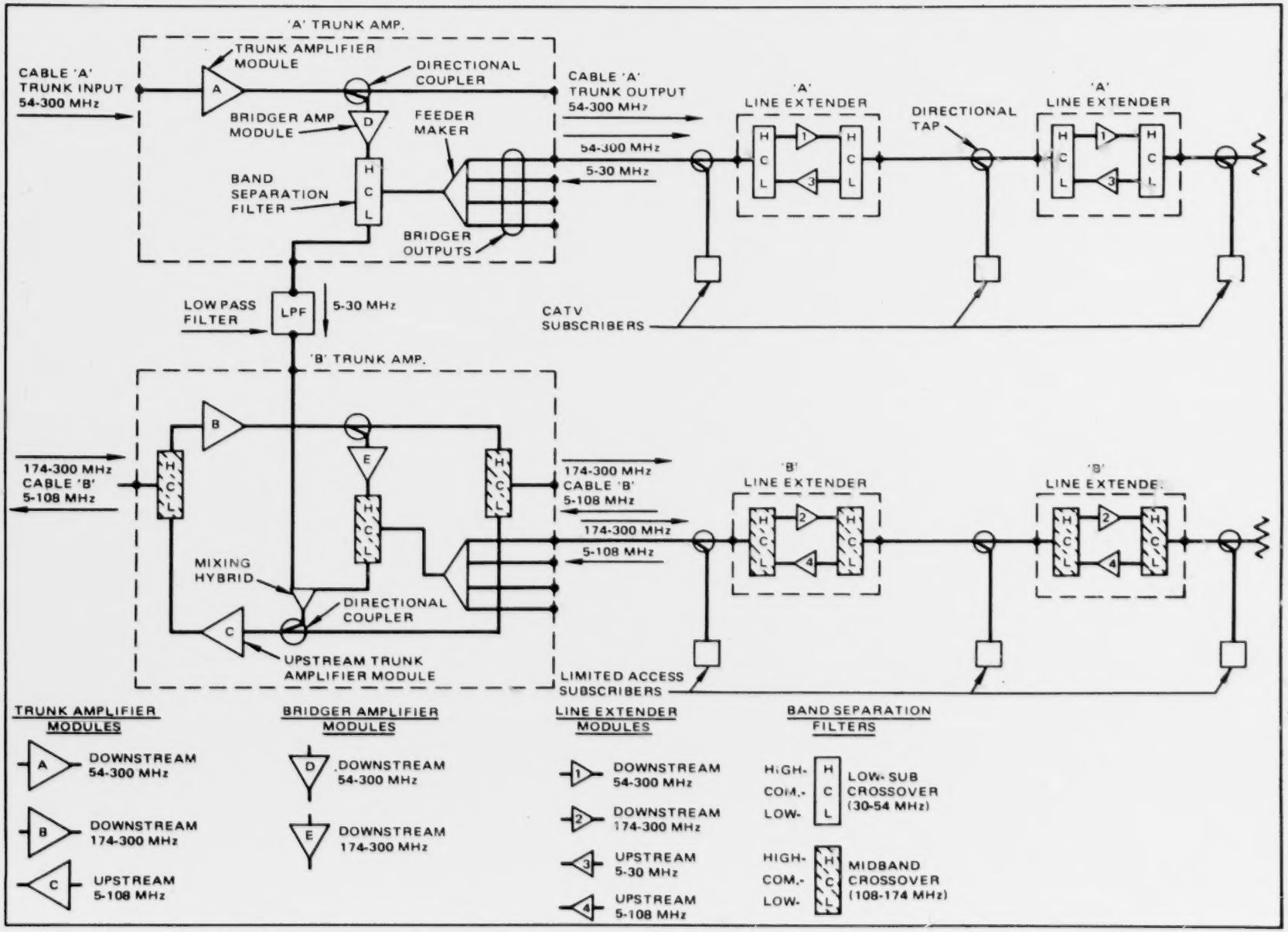

Figure 7 - El Segundo CATV/SRS System Block Diagram

Figure 8 - Two Cable Two-Way Cascade

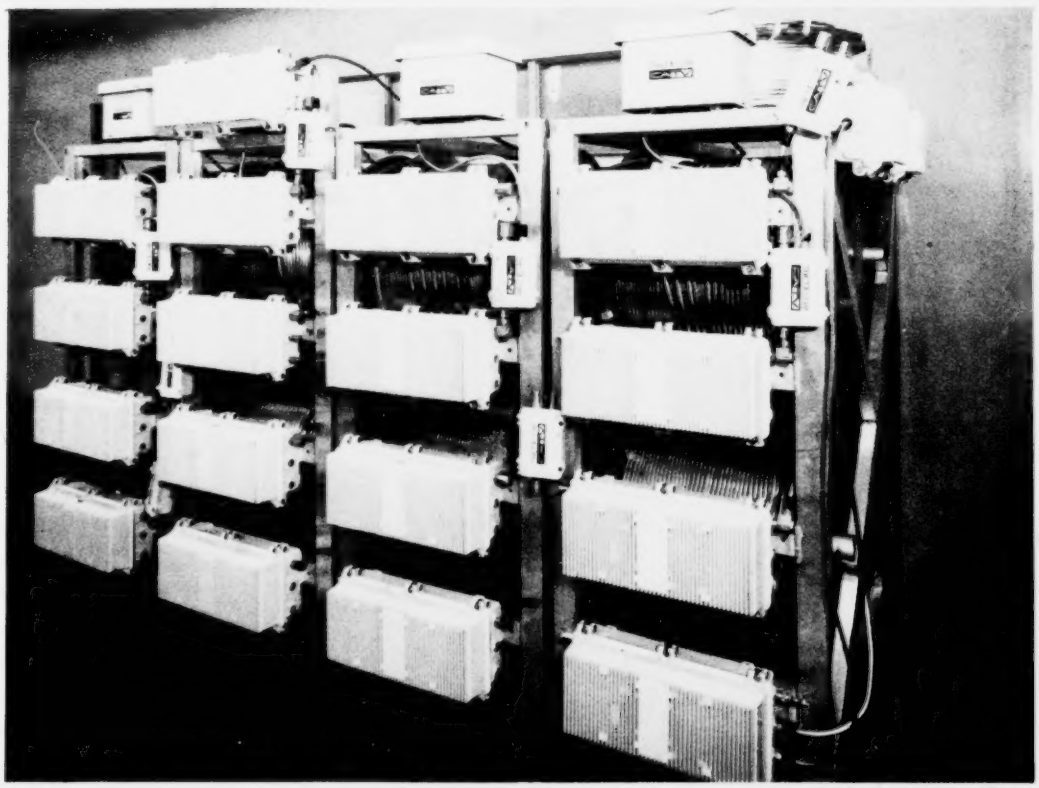

Figure 9 - Single Cable Two-Way Cascade

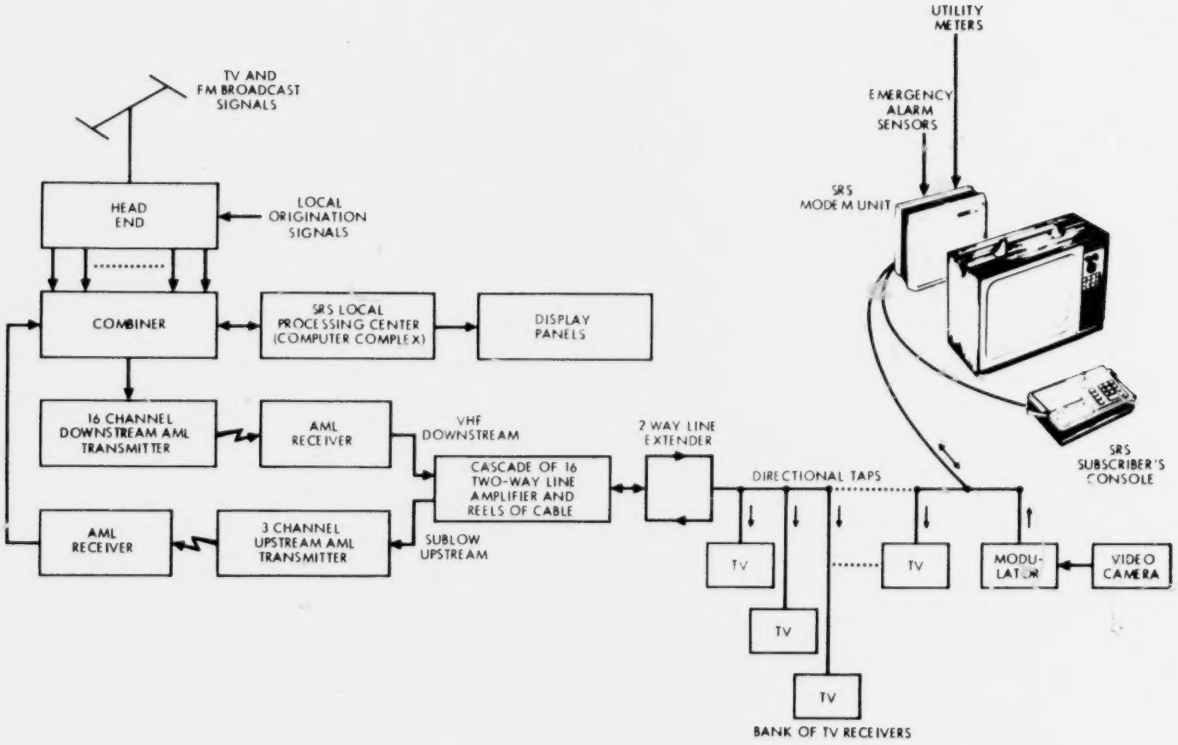

Figure 10 - Combined SRS-LDS Operation

Figure 11 - Single Cable Retrofit Two-Way Cascade

Figure 12 - SRS Computer Display

Figure 13. El Segundo Headend Building

Figure 14. SRS Local Processing Center -
Headend Installation

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EL SEGUNDO CABLE SYSTEM

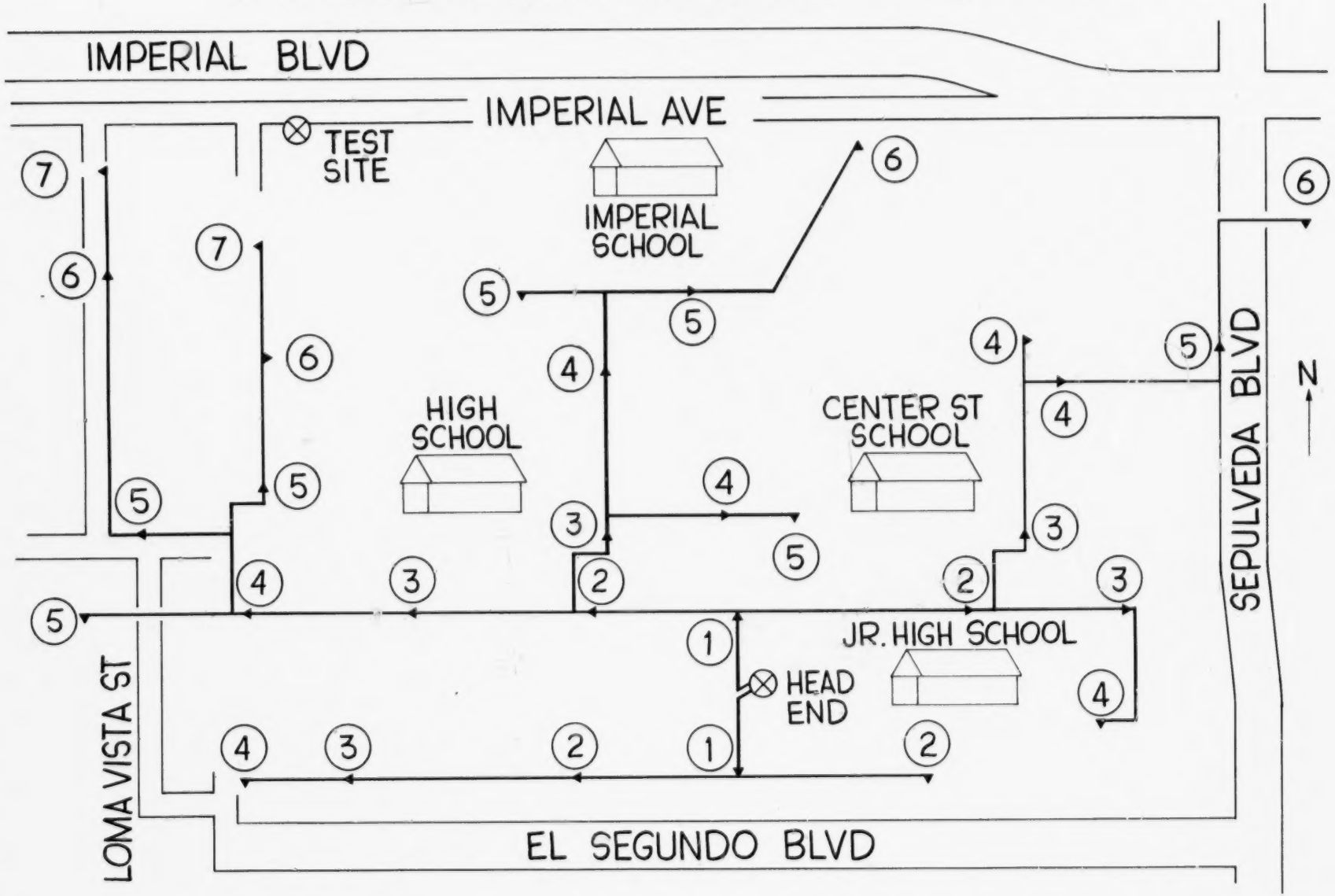

Figure 15. El Segundo CATV System Diagram

Figure 16. SRS Terminal Installation
El Segundo Apartment